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Electrokinetic Dewatering of Softwood Furnishes

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by

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ABSTRACT

Enormous quantities of water are required in the preparation and formation of paper products. One of the most costly operations in paper manufacture is removal of excess water from the sheet and disposal of by-products from paper production. Currently, high steam energy is necessary in the drying process of paper manufacture. Disposal of a paper by-product, sludge, is also a rising concern due to environmental risks, shrinking landfill space, and rising disposal costs. Both production costs and disposal costs could be reduced with a more effective and efficient process to enhance water removal in paper production and sludge disposal.

One possible way to reduce operation and disposal costs while minimizing the environmental impact of industry is electrokinetics. Electrokinetics is an electricity-driven separation process which was used in this thesis to assist water removal in a softwood furnish.

A bench scale pressing device capable of pressing a softwood furnish between two charged wire screens was used examine the effect of electrolyte concentration on water removal. Variables in this experiment included ion concentration and freeness. Different levels of alum were added to a softwood furnish and final pad consistency was compared to control runs which excluded current and alum additions.

The results indicated that for higher freeness pulps, the addition of alum in the electrokinetic press increased final pad consistency. However, for lower freeness pulps alum seemed to inhibit water removal. Further studies in applying electrokinetics should include the use of different cationic sources.

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INTRODUCTION

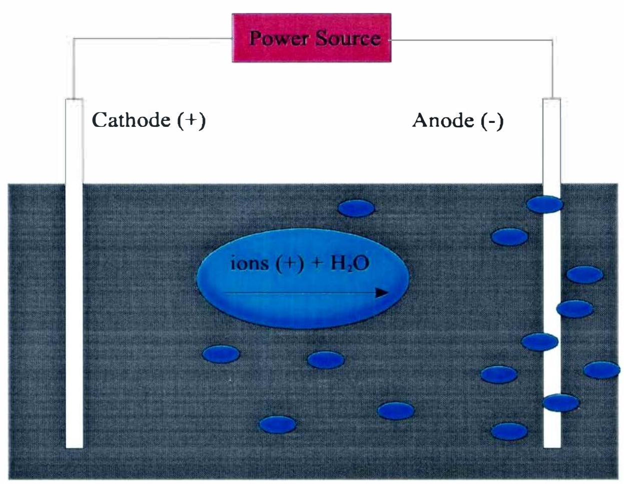
Electrokinetics has been an effective dewatering tool for the mining and clay industry and has been useful in the remediation of contaminated soil, silts, and sludge (1). In the paper industry, electrokinetics could be used to assist in the separation of water from fiber in a fiber mat or from sludge prior to disposal. Both cases would have economical benefits. An effective alternate water removal process on the paper machine would replace conventional steam energy requirements and lower operating costs. Other costs that could be reduced is sludge disposal costs. A more thorough separation of water from non-water components of sludge would reduce the mass and volume of material sent to landfills. Understanding further benefits and other applications of electrokinetic separation is the focus of this thesis.

The two primary objectives of this thesis were to examine the effect of alum as a cationic source in aiding electrokinetic dewatering of a softwood furnish. The second objective was to get a better understanding of how freeness affects electrokinetic dewatering.

BACKGROUND

Electrokinetics refers to the movement of particles within an electric field. This electric field is introduced via electrodes or cells. Past research has shown that the electric potential causes positive ions to migrate towards the negative electrode carrying water molecules with them (2). The water molecules are then released at the anode and removed from the compound. Figure 1 shows this process.

Figure 1



Electrokinetics can be divided into two sections, electro-osmosis and electrophoresis. Electro-osmosis refers to the movement of a conducting liquid through a porous medium. This is derived in terms of liquid flow through a capillary. The driving force of an electro-osmotic flow is the pressure differential. This pressure differential is proportional to the zeta potential of the capillary walls, the dielectric constant of the liquid, and the electric field strength (3). The second section, electrophoresis, refers to the movement of suspended particles through a fluid. This movement occurs when a charged particle charged particle interacts with the applied electric field and particle migrates towards the electrode of opposite charge.

Electrokinetics has also been used in a landfill study (4). Electrodes which had the ability for water to pass through and be collected were inserted into two different landfills. At the end of forty days, the solids level increased by an average of 18.5%.

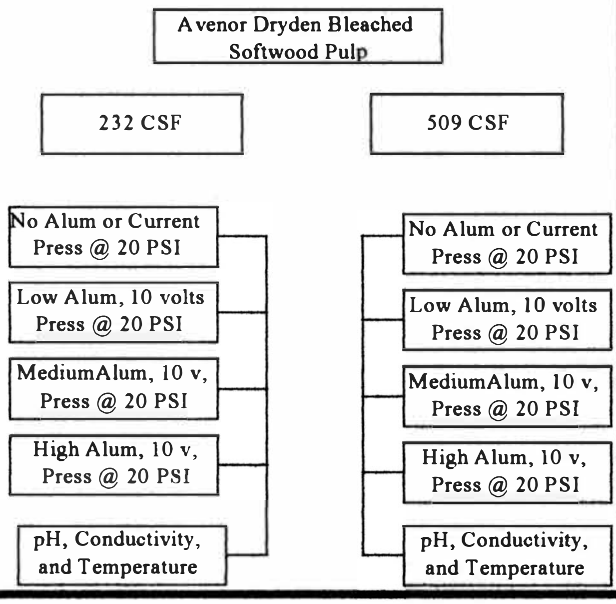
Two other WMU thesis studies have been done on electrokinetics. One student showed that an electric current applied via wire screens improved dewatering of sludge under gravity conditions (5). Another student examined the effects of an electric field on sludge under pressure (6). Using a bench-scale electrokinetic sludge press, this student optimized the voltage and cathode/anode arrangement. He found that 10 volts with the lower screen as the anode resulted in the best sludge dewatering.

PROCEDURE

Softwood Furnish Preparation. Avenor Dryden bleached softwood kraft pulp was refined to 232 and 509 Canadian Standard Freeness using the laboratory Valley Beater. Alum was added prior to each run and will be described later.

Experimental Design. The experimental design consisted of eight runs. Four runs for each freeness level. At each freeness level, a control run and three runs with different

Figure 2 - Setup

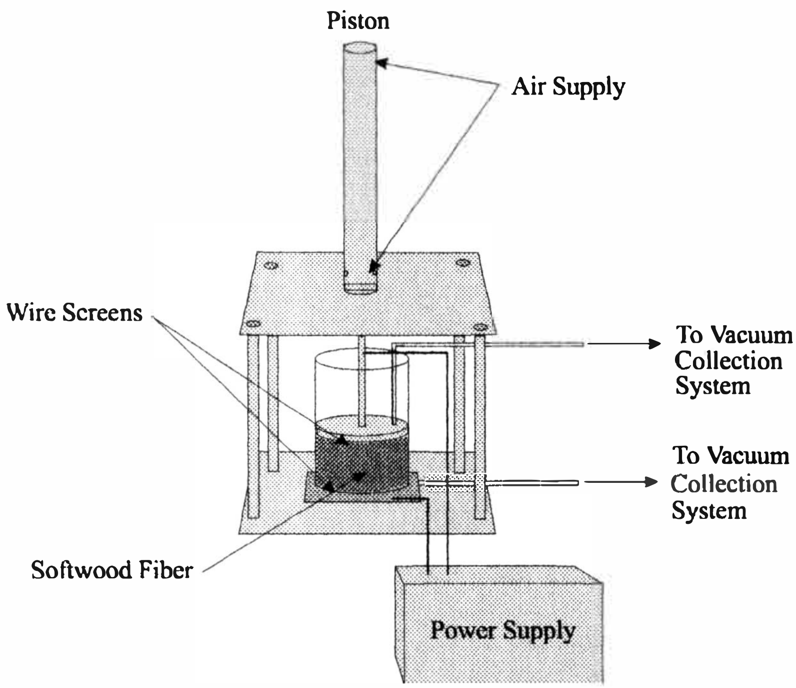


alum additions were done. Figure 2 shows the design of the experiment. Conductivity, pH and temperature were measured prior to each run. The above procedure was carried out four times for repeatability.

Electrokinetic Apparatus. The electrokinetic apparatus used was constructed for a previous thesis that examined different voltage levels and electrode arrangements (6). The device consists of an acrylic tube, several acrylic disks glued together designed to fit in the end of the tube, a pneumatic piston, two fine mesh screens, two large mesh screens, and a vacuum system. The wire screens were placed in the bottom of the acrylic cylinder and on the piston head. These screens were charged by screws that were connected by wires to the DC power source.

Figure 3

Experimental Design



Two vacuum flasks were used to assist the water removal from the cylinder. Water could be removed from the top through a hole in the piston head, and water could be removed from a hole in the bottom of the cylinder. Figure 3 shows the apparatus.

Procedure. For each run, approximately 175 ml of furnish was added to the cylinder. The top wire screens were dropped on top of the furnish and the press was lowered.

When the piston reached the top surface of the furnish, 10 volts were applied. The furnish was pressed a 20 psi for two minutes. At the end of two minutes, the press was raised and the current shut off. The fiber pad was then removed from the cylinder, dried on a hot plate for 10 minutes, and weighed. Final pad consistency was calculated and recorded.

The total amount of water removed from the furnish was recorded as well as the distribution between water removed from the top and the bottom.

Alum Addition. At 232 CSF the medium alum level consisted of 10 ml of a 1% alum solution by weight. The high alum solution consisted of 10 ml of a 4% alum solution by weight. For the 509 CSF furnish the medium alum level consisted of 3 ml of a 4% solution, while the high alum level used 10 ml of a 4% alum solution.

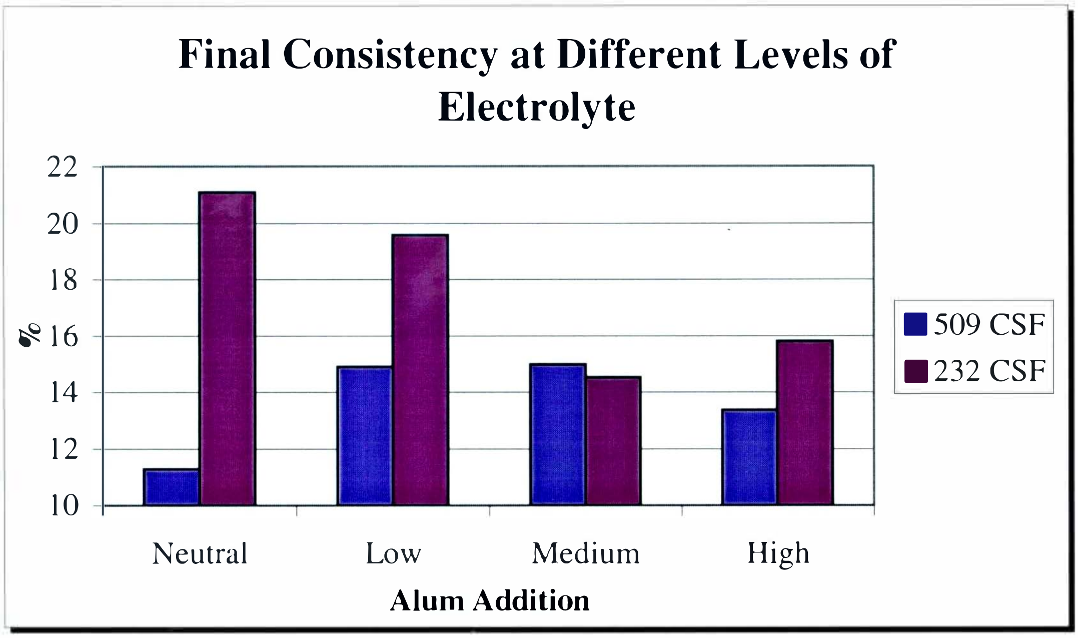
RESULTS

The results for the softwood furnish refined to 232 CSF are shown in Appendix 1. Final pad consistency averaged 21% for low alum concentration runs, 19.6% for the medium alum concentration runs, and 15% for the high alum concentration runs.

As one might expect, control runs in which the furnish was dewatered by pressing only, the 509 CSF furnish had higher final pad consistencies.

The results for the softwood furnish refined to 509 CSF are shown in Appendix 1. The control run (press only) average final pad consistencies was 11.3%. Final pad consistencies ranged from 14.9% to 15% for low alum concentrations to medium concentrations. High alum concentration average consistency dropped to 13.4%. The initial consistency of the furnish ranged from 1.3% to 1.6%.

Figure 4

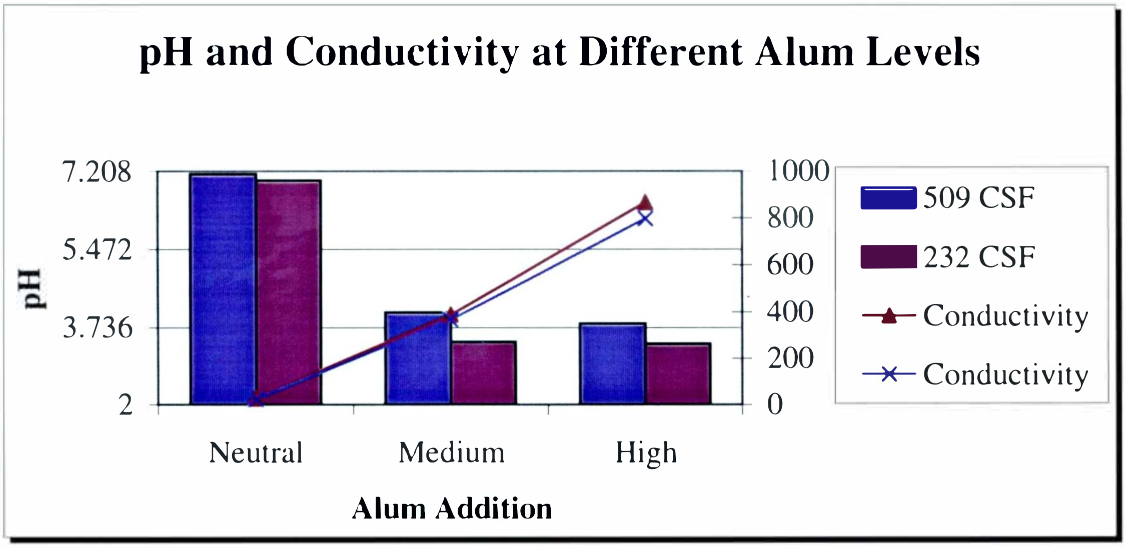


Only the 509 CSF furnish showed improved dewatering as the alum concentration increased. However, it increased up to the medium concentration level and decreased at the high alum level.

The 232 CSF furnish had its maximum dewatering when no current or alum was added. One hypothesis for this result is retention of water molecules on fibers and fines. Lower freeness furnishes would have smaller fiber lengths and increased fines when compared to higher freeness furnishes. In lower freeness furnishes, water molecules are more likely to be intercepted by fines or fibers as the molecule moves towards the anode. The concentration of alum in conjunction with the electric potential may have inhibited water removal even further due to this "retaining" effect.

pH and conductivity were also measured during each run. Figure 5 shows the results.

Figure 5

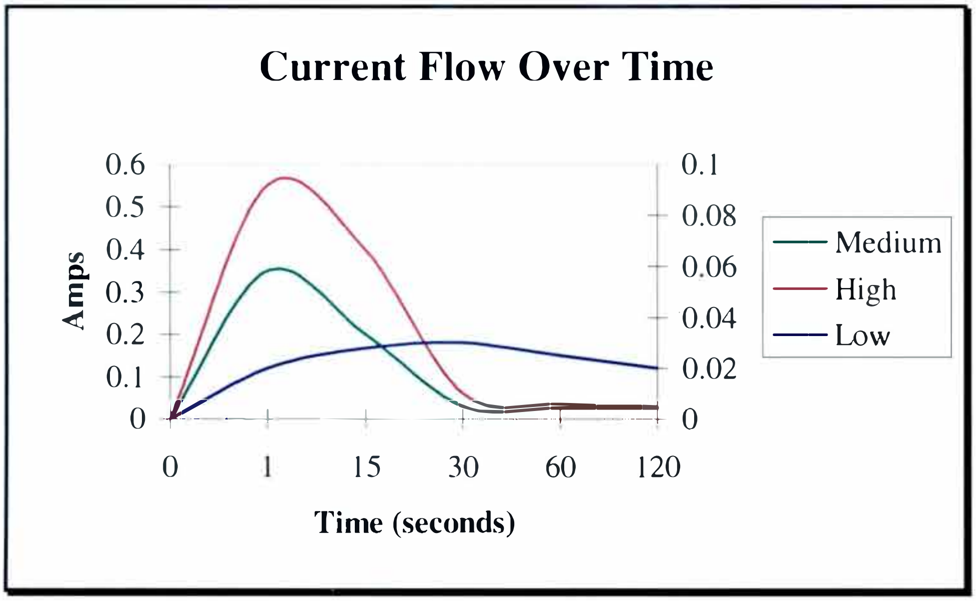


pH for neutral and low alum additions were between 7.0 and 7.2. At the medium and high additions pH dropped off quickly to 3.1 to 3.4 for 232 CSF furnishes and 3.8 to 4.1 for 509 CSF furnishes.

Conductivity was measured in µmho/cm, and as expected, the conductivity increased as the level of alum increased. However, increased conductivity did not result in better water removal for the lower freeness furnish.

Another interesting aspect of the dewatering process was monitoring the current flow over time. Figure 6 shows the current flow over time at each alum level.

Figure 6



Note: Low alum level was plotted on the right axis to better show the current flow over time trend.

Current flow for the low alum additions showed an interesting trend. The current flow slowly increased for the first 30 seconds while the fiber mat compressed and then it leveled off and decreased the last 90 seconds. This suggests the significance of the gap between electrodes. At the point when the fiber mat was compressed to its minimum thickness the current was at its maximum. As the water was removed from the pad, current flow decreased as resistance increased. This should be true since V = IR

Where V = voltage (volts)
I = current flow (amperes)
R = resistance (ohms)

Voltage was held constant at 10 volts.

Medium and high alum additions showed a slightly different trend. They still should exhibit similar trends as the low alum addition had, but it was masked by the sudden thickness the current was at its maximum. As the water was removed from the pad, current flow decreased as resistance increased. This should be true since $V = IR$

$$\begin{aligned} \text{Where } V &= \text{voltage (volts)} \\ I &= \text{current flow (amperes)} \\ R &= \text{resistance (ohms)} \end{aligned}$$

Voltage was held constant at 10 volts.

Medium and high alum additions showed a slightly different trend. They still should exhibit similar trends as the low alum addition had, but it was masked by the sudden jump in current when the top electrode came in contact with the surface of the furnish. The sudden jump is attributed to the increased electrolyte concentration of the furnish. Higher electrolyte concentrations result in greater current flow.

An increase in current flow due to higher ionic concentration in the furnish did not necessarily result in greater water removal. It seems that furnish composition overrides the electrokinetic effect.

CONCLUSIONS

The results of this experiment showed that applying an electric potential to a furnish under pressure to assist dewatering is beneficial only for certain applications. Low freeness furnishes optimum dewatering conditions occurred when no voltage or alum was added. Higher freeness furnishes, however, had higher pad consistencies with the electric potential at medium alum concentrations.

The effect of ionic concentration did affect current flow but it did not necessarily result in higher pad consistencies.

Recommendations

Before this process can be applied on a larger scale, more research is necessary to optimize the operating variables. I would recommend that further study be done with furnish water removal using other cationic sources, possibly polymers which do not affect the pH as drastically. Experimentation should also be done with lower initial consistency and thinner fiber pads. Other studies might focus on the effect of electrokinetics on fines retention. This would be beneficial in wet-end chemistry applications.

Other studies using the electrokinetic press device should be done with simulated sludge using coagulating polymers.

References

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Experimental - Raw Data

Avenor Dryden Softwood Furnish (232 CSF)

Run Number	Total Wt (grams) (sample+beaker)	Sample Wt (grams)	pH	Conductivity (µmho/cm)	Water Removal (ml) Top	%	Bottom	%	Total (ml)	Pad Wt (grams)	Consistency (%)	Final Consistency %		
Neutral (no alum or current)														
1	269.8	169.3		20					120.0	2.73	1.61	29.12		
2	273.2	172.7	7.01	28	50	37.0	85	63.0	135.0	2.48	1.44	21.83		
3	275	174.5	6.97	28	49	35.3	90	64.7	139.0	2.55	1.46	20.34	21.09	Average
Low (0 Alum)													1.05	Stdev
4	256	155.5			88	72.7	33	27.3	121.0	2.5	1.61	22.19		
5	255	154.5		28	54	36.5	94	63.5	148.0	2.48	1.61	4.21		
6	249.5	149		28	23	18.9	99	81.1	122.0	2.38	1.60	18.12		
7	257.4	156.9		28	25	19.5	103	80.5	128.0	2.51	1.60	18.42	19.58	Average
													2.27	Stdev
2 ml of a 1% alum solution														
8	258	157.5		66	19	14.2	115	85.8	134.0	2.48	1.57	14.92		
9	263	162.5	3.4	62	21	14.9	120	85.1	141.0	2.63	1.62	13.23	14.08	Average
													1.19	Stdev
Medium (10 ml of a 1% alum solution)														
10	258.1	157.6		400	22	14.9	126	85.1	148.0	2.53	1.61	6.09		
11	268.1	167.6	3.3	320	24	16.1	125	83.9	149.0	2.48	1.48	11.10		
12	265.5	165	3.39	395	19	13.7	120	86.3	139.0	2.52	1.53	15.76		
13	286.9	186.4	3.53	450	30	19.6	123	80.4	153.0	2.61	1.40	17.92	14.92	Average
													3.49	Stdev
High (10 ml 4% alum solution)														
14	265	164.5	3.52	920	26	18.6	114	81.4	140.0	2.45	1.49	14.89		
15	272.2	171.7	3.19	900	10	7.1	130	92.9	140.0	2.45	1.43	18.46		
16	272.7	172.2	3.4	800	14	9.5	134	90.5	148.0	2.54	1.48	14.05	15.80	Average
													2.34	Stdev
Avenor Dryden Softwood Furnish (509 CSF)														
Control (no alum or current)														
17	275.7	175.2	7.12	26	28	18.2	126	81.8	154.0	2.63	1.50	12.10		
18	274.3	173.8	7.16	26	15	9.9	137	90.1	152.0	2.56	1.47	12.54		
19	275.5	175	7.15	27	24	15.1	135	84.9	159.0	2.42	1.38	9.14	11.26	Average
Low (0 alum solution)													1.85	Stdev
20	252.3	151.8	7.1	22	10	7.8	119	92.2	129.0	1.88	1.24	15.02		
21	262.8	162.3	7.37	24	0	0.0	132	100.0	132.0	2.25	1.39	18.67		
22	279.7	179.2	7.12	30	17	10.7	142	89.3	159.0	2.64	1.47	11.27		
23	276.2	175.7	7.47	27	4	2.7	146	97.3	150.0	2.49	1.42	14.63	14.90	Average
													3.03	Stdev
Medium (3 ml of a 4% alum solution)														
24	277.8	177.3	4.15	320	0	0.0	144	100.0	144.0	2.38	1.34	18.78		
25	282.3	181.8	4.03	380	33	20.0	132	80.0	165.0	2.45	1.35	9.24		
26	286.7	186.2	4.01	410	2	1.2	163	98.8	165.0	2.4	1.29	11.39		
27	282.3	181.8	4.07	380	0	0.0	155	100.0	155.0	2.32	1.28	14.74	14.97	Average
													3.70	Stdev
High (10 ml of a 4% alum solution)														
28	266.8	166.3	3.75	560	0	0.0	145	100.0	145.0	1.99	1.20	12.81		
29	287.5	187	3.87	590	113	72.0	44	28.0	157.0	2.22	1.19	16.04		
30	275	174.5	3.86	1000	0	0.0	150	100.0	150.0	2.33	1.34	14.04		
31	276	175.5	3.76	1000	25	15.9	132	84.1	157.0	2.26	1.29	10.54	13.36	Average
													2.30	Stdev